Gamma Spectrometric techniques

for Ultra Low Activity Measurements

Underground Facilities

Anti Cosmic and Anti Compton Radiation Shield Systems

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"Marine" Environment Laboratories

Monaco

Why Low Activity Measurements are needed ???

- 40-50 years after the introduction of anthropogenic radionuclides into the environment their concentrations have decreased considerably
- Highly accurate and precise data are required for environmental and climate change studies
- Sample size for radiometrics analyses should be comparable to mass spectrometry requirements

Developments in radiometrics techniques :

- ***The operation of high efficiency HPGe detectors often placed underground***

  Low activity → High efficiency detector

  High efficiency detector → Higher sensitivity to background and cosmic rays

  Sensitivity to the background → Ultra low Background Lead Shield

  Sensitivity to the cosmic rays → Deep Underground Lab

- ***Anti-cosmic and anti-Compton shielding of detectors***

  Not deep enough U-Lab → Anti Cosmic shield

  Background coming from sample → Anti-Compton system

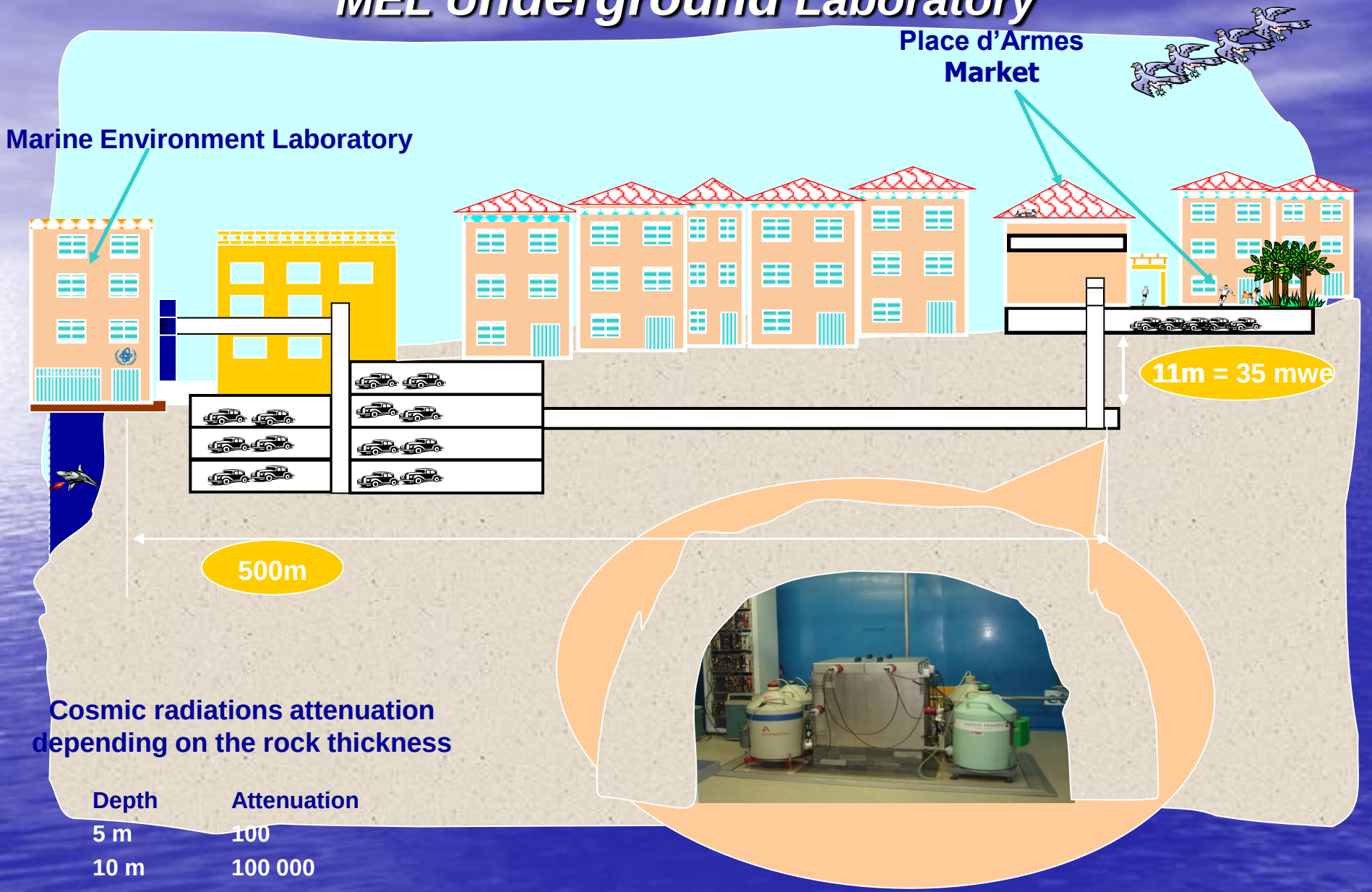
- ***Coincidence gamma-ray spectrometry (γ-γ, β -γ, β -γ-γ, etc.)***

  Background still too high → γ–γ coincidences

  Background still too high → B–γ, B–γ–γ, coincidences etc …

Underground Laboratory

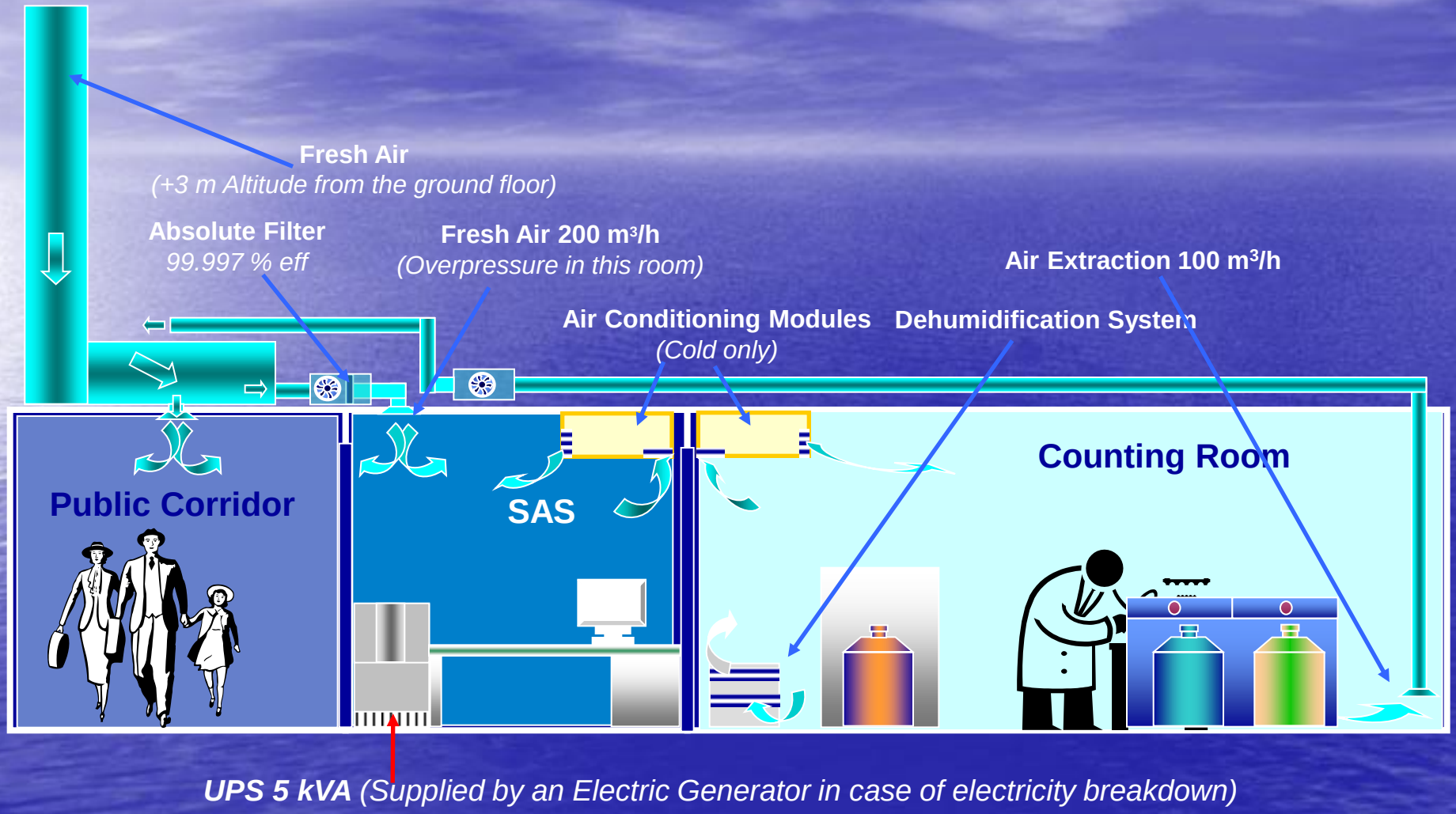
MEL Underground Laboratory



Cosmic radiations attenuation depending on the rock thickness

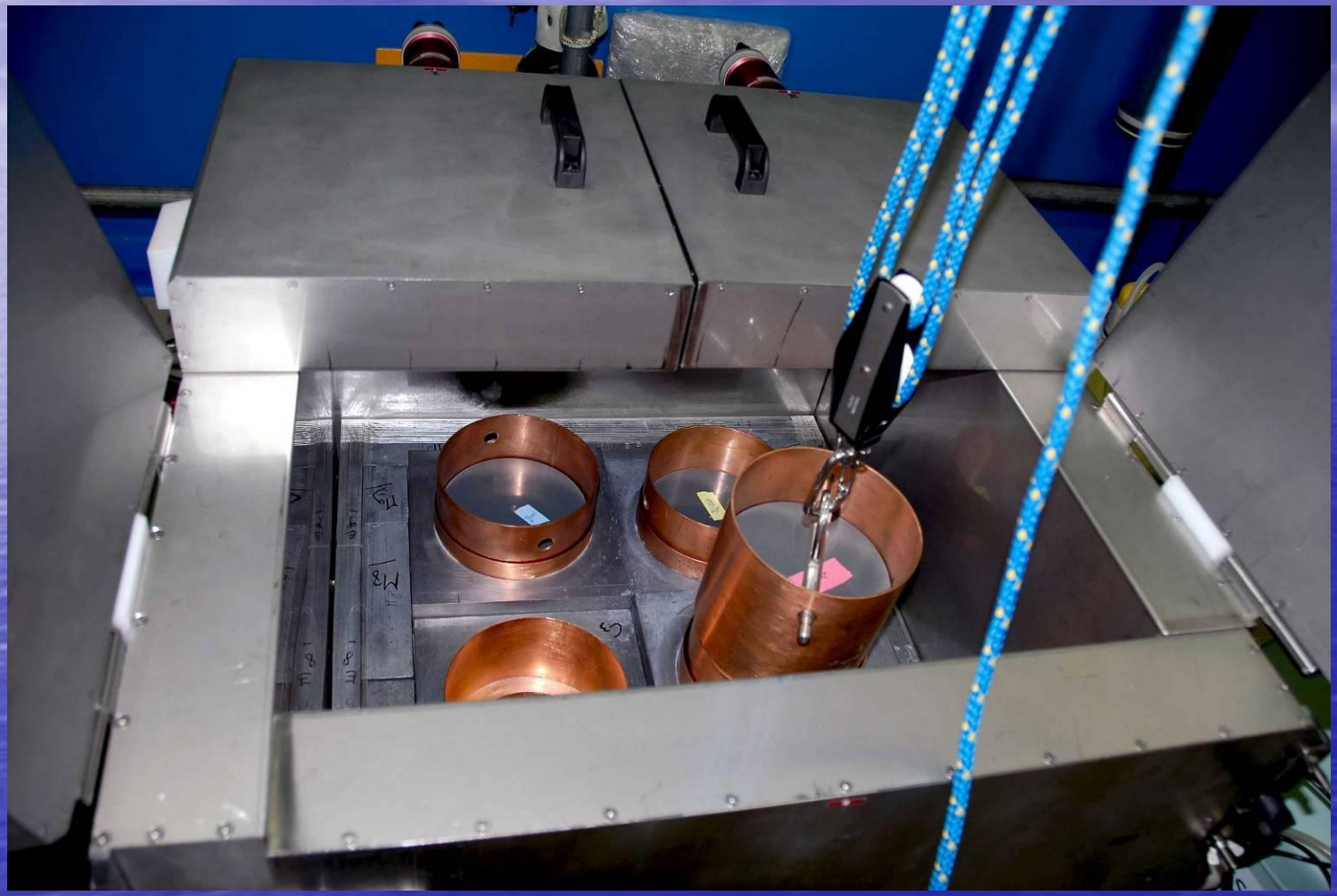
Depth	Attenuation
5 m	100
10 m	100 000
50 m	10 000 000
100 m	100 000 000
1000 m	1 000 000 000

UNDERGROUND LABORATORY
Fresh Air, Air Conditioning, Electricity

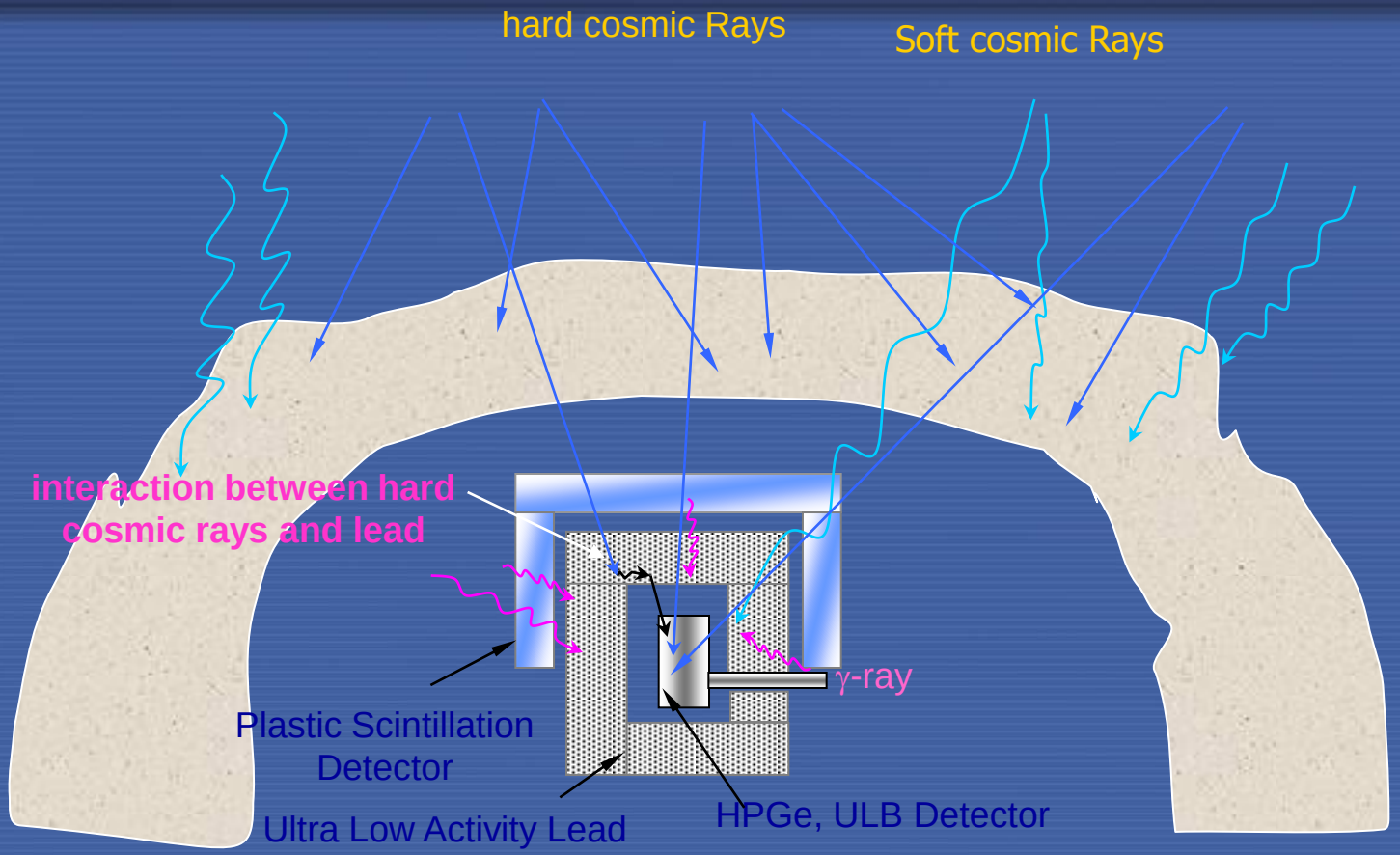


MEL Underground Laboratory

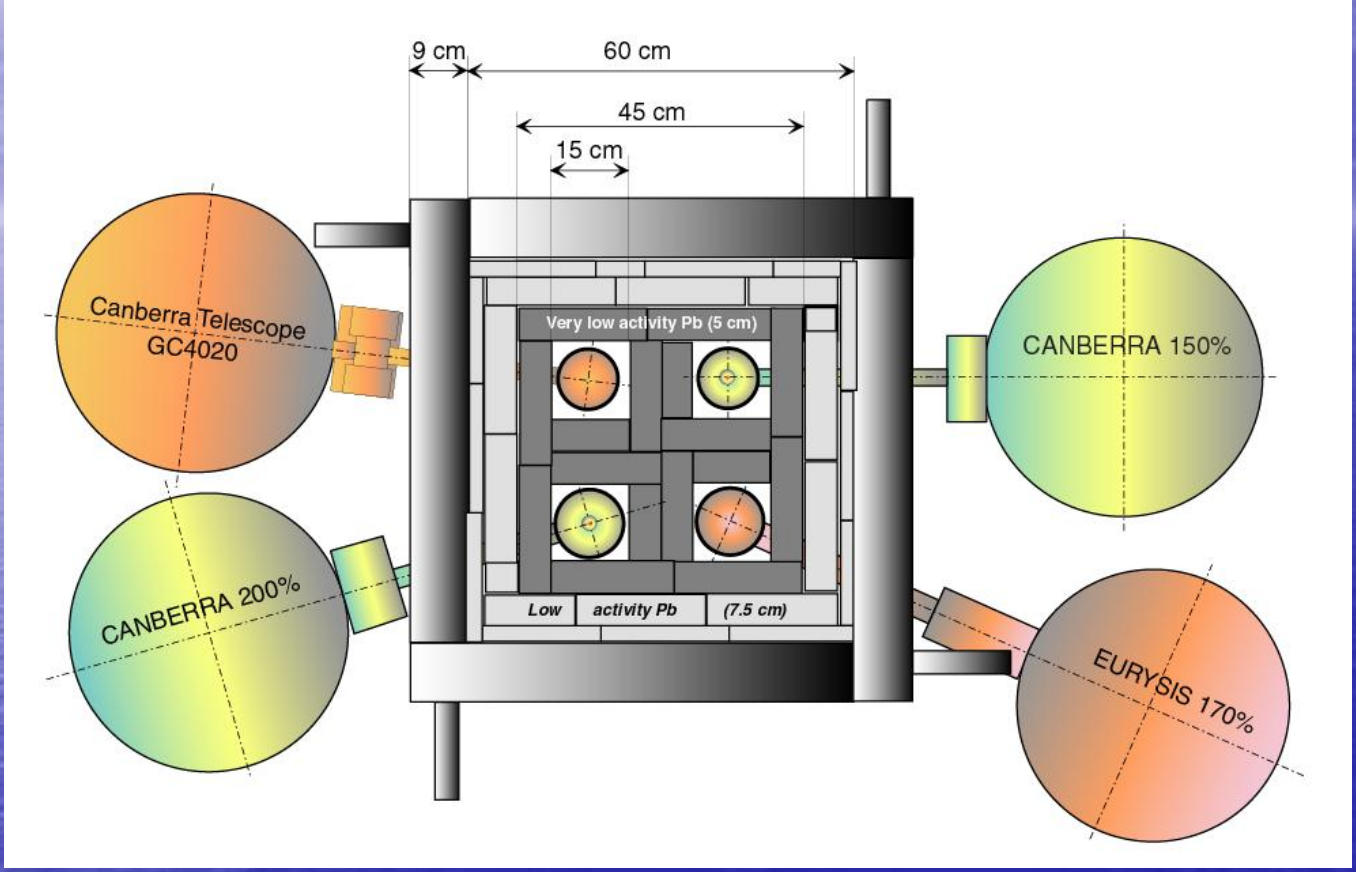
Anti-cosmic Spectrometers



Anti-cosmic spectrometers Principle

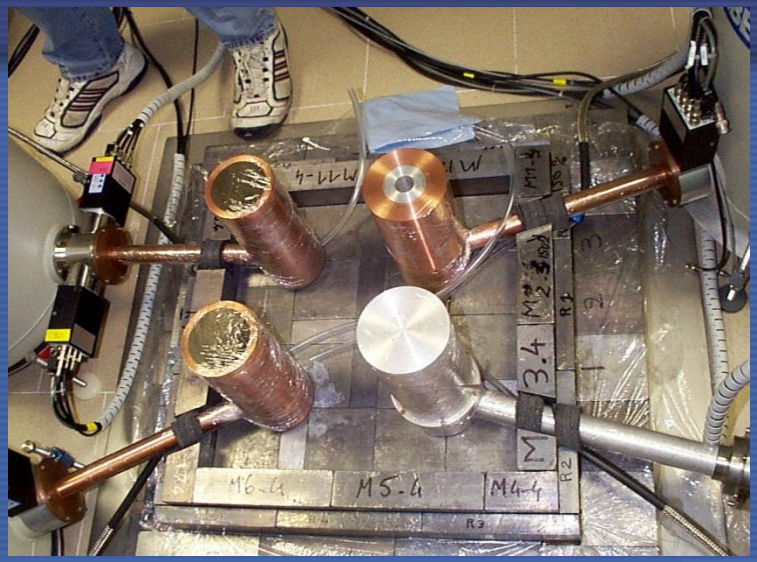


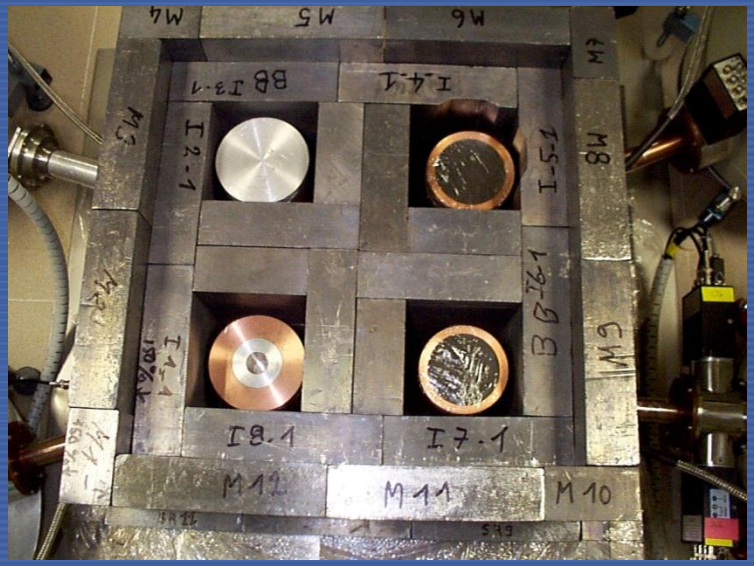
The system operates in anti-coincidence mode



View of the lead shield with anti-cosmic plastic scintillation shielding

Anti-Cosmic Spectrometers





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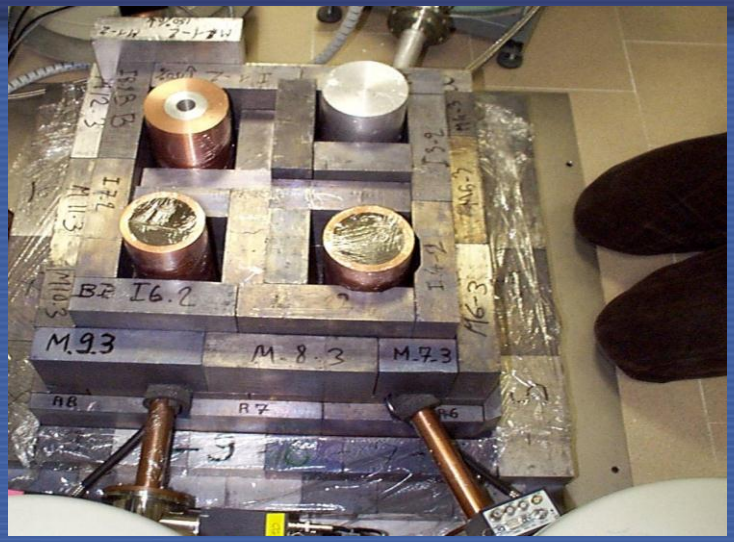
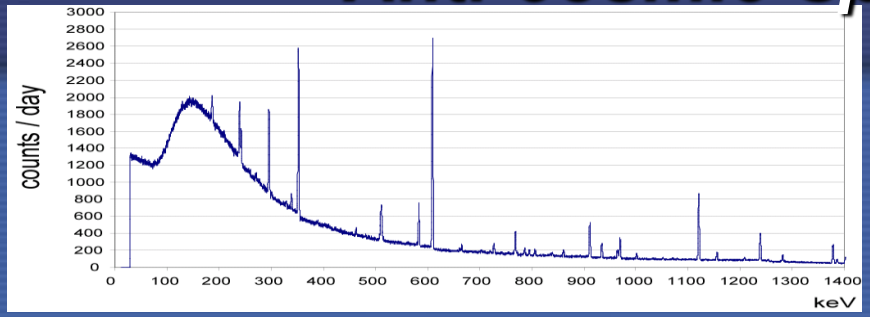
Anti-cosmic Spectrometers



Anti-Cosmic Spectrometers

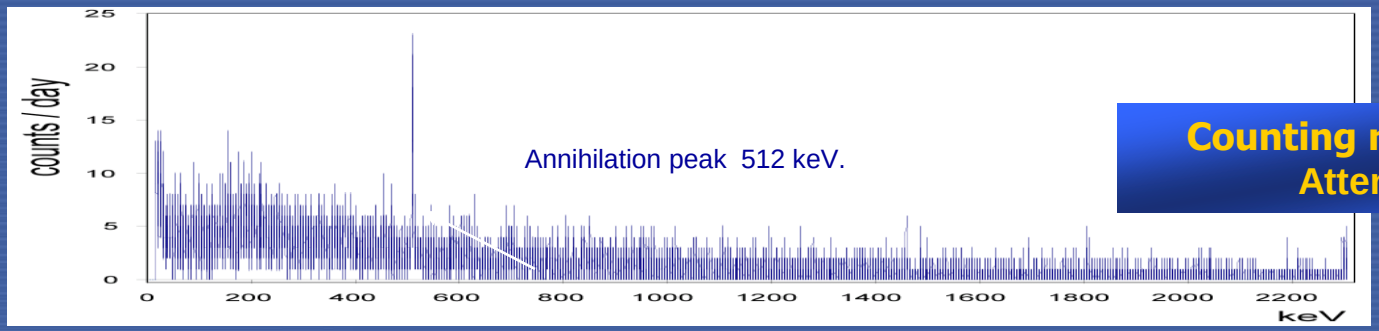
Anti-cosmic Spectrometers

Anti-cosmic Spectrometers



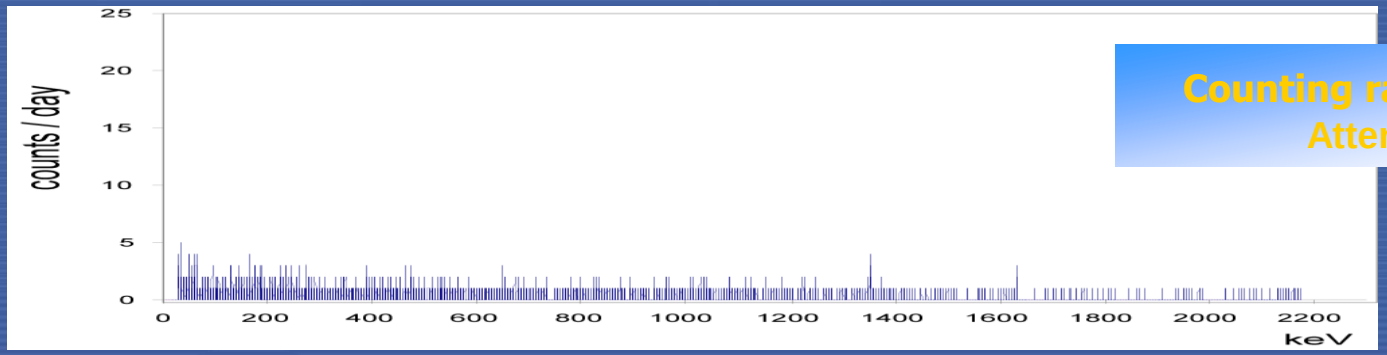
Counting rate = 5,2 10^6 c/d

Background without lead shield and without electronic anti-cosmic system.



Counting rate = 1,728 10^4 c/d
Attenuation : 307

Background with lead shield and without electronic anti-cosmic system.

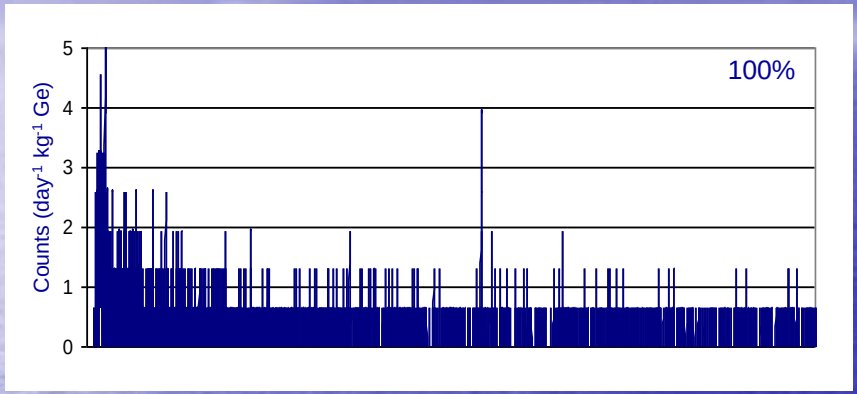


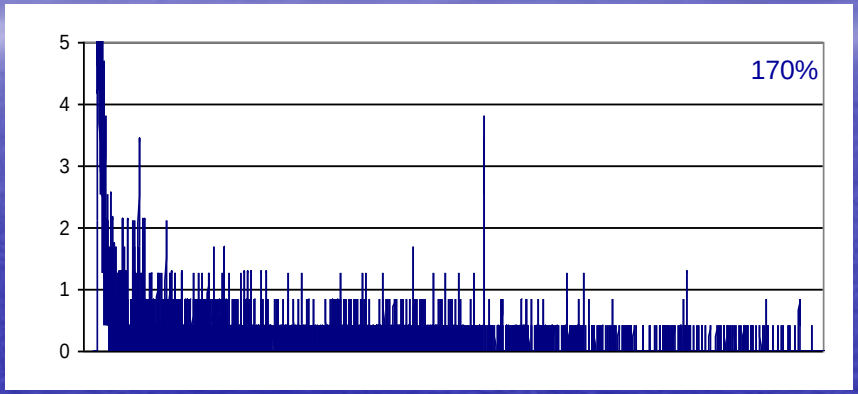
Counting rate = 1,728 10^3 c/d
Attenuation : 10

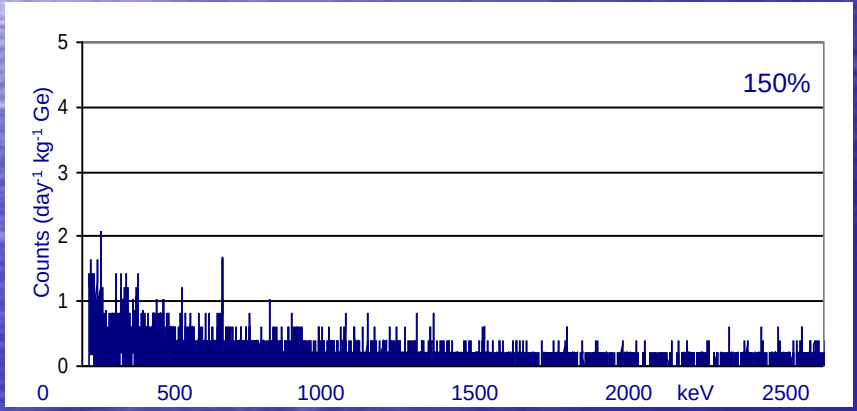
Background with lead shield and with electronic anti-cosmic system.

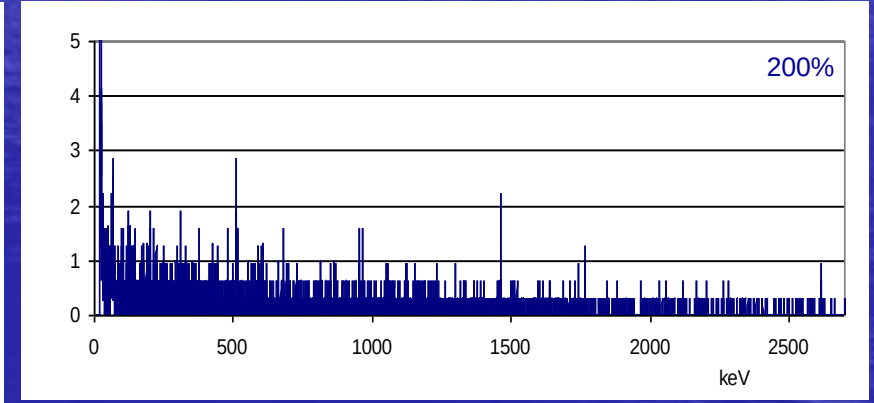
Anti-cosmic Spectrometers

BACKGROUND GE-SPECTRA WITH ANTICOSMIC SHIELDING

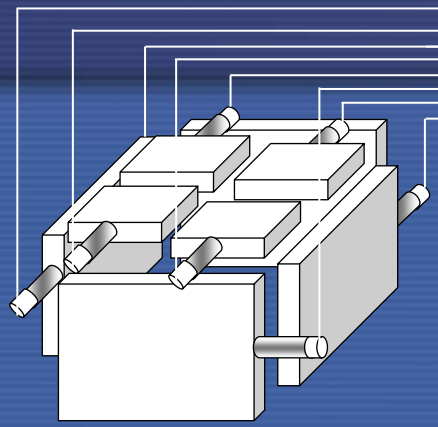






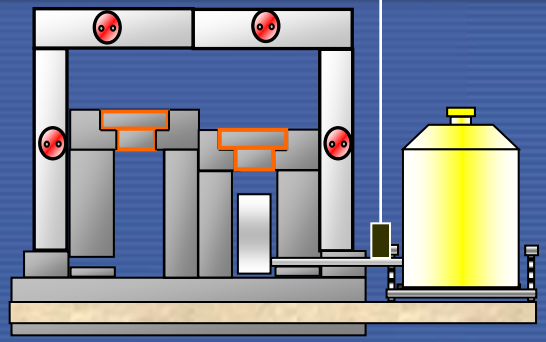


Anti-cosmic Spectrometers



Photomultiplicateurs scintillateurs plastiques

Détecteurs HP-Ge



Summing preamplifier

Preamplifier

Time 2 Time 1 Energy

Fast Amplifier

Fast Amplifier

Constant Fraction discriminator

Constant Fraction Discriminator

4 3

Calibrated Delay

5

Linear Amplifier

Time Amplitude Converter

6

Delay and Shape

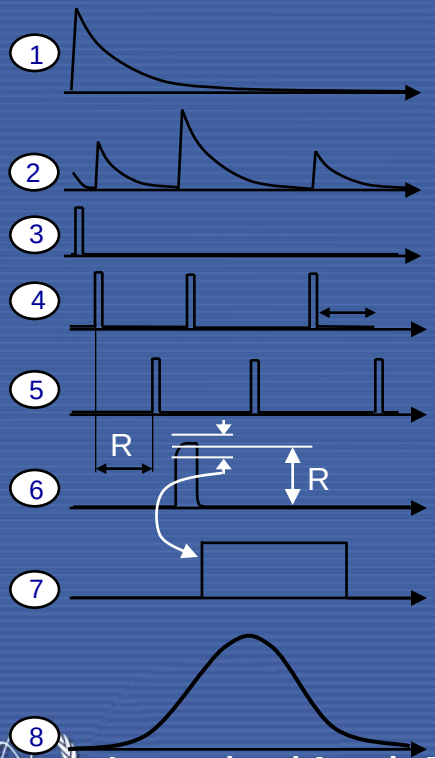
7 8 8

Gate Input

Multi Channel Analyser

Gate input

Multi Channel Analyser



Anti-cosmic Spectrometers

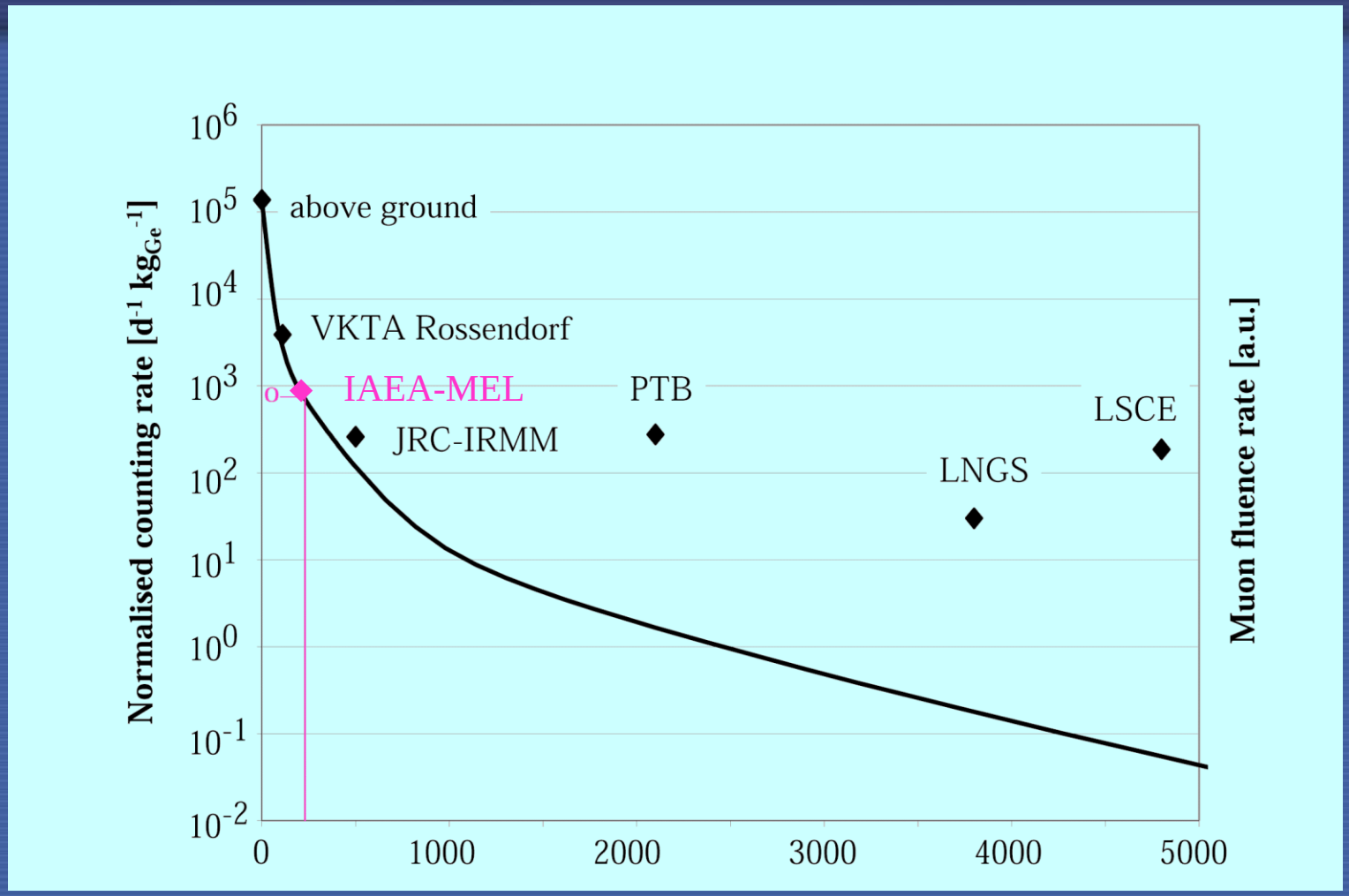
Comparison with other U-Lab

Low-background gamma spectroscopy for environmental spectroscopy T.M. Semkow and all. Applied Radiation and Isotopes 57, 213-2232002

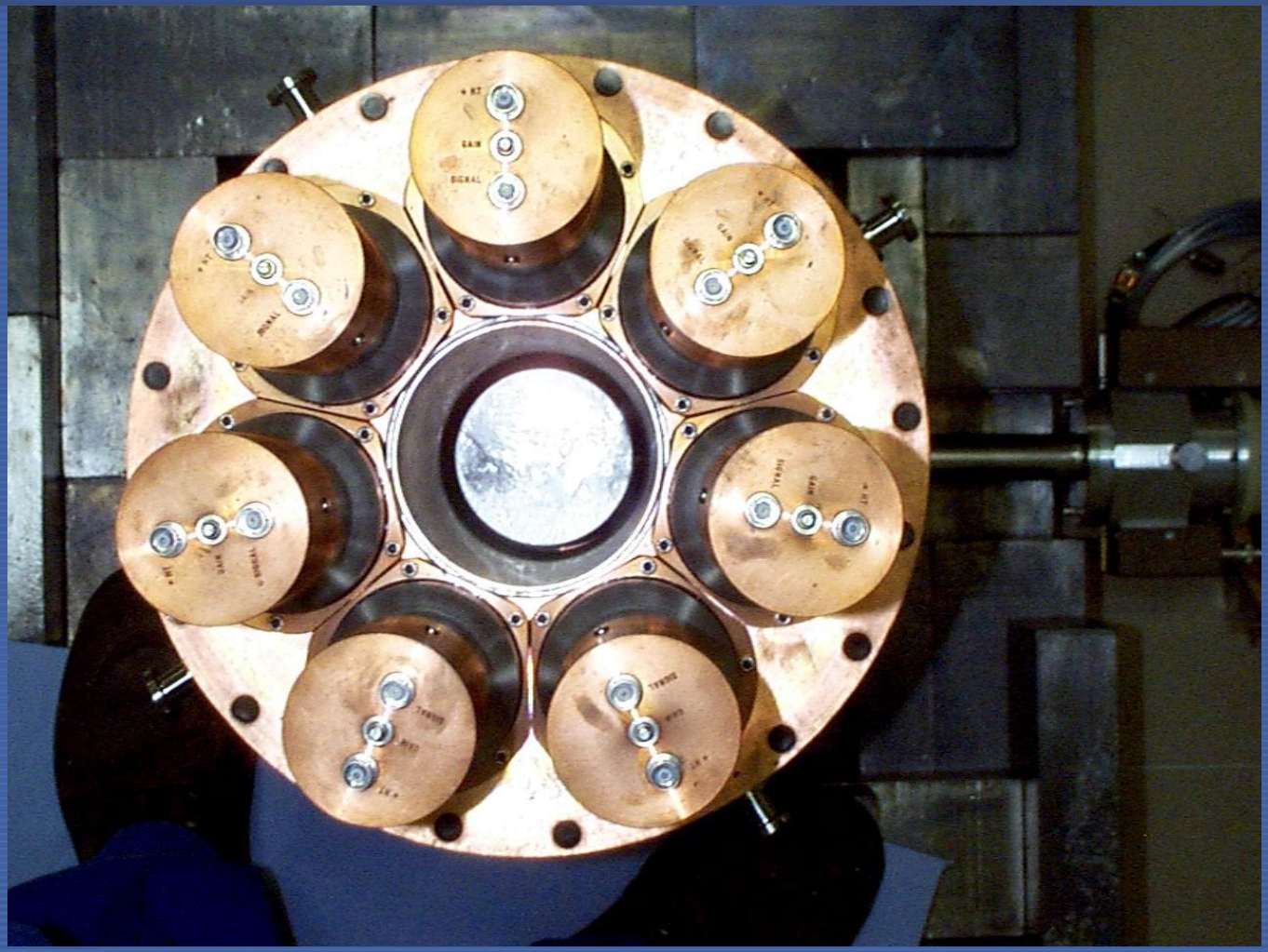
Localization Meters Water Equivalent (mwe).	Active Shield	Volume of Ge (Cm^3)	Energy Range (keV)	Background ($c/s/100cm^3$)	References
Ground Level	Plastic Scintillator 4 faces	131	40-3000	$2,1 \times 10^{-1}$	Shizuma (1992)
Ground Level	Proportional Counter at the top	180	50-1500	$1,4 \times 10^{-1}$	Vojtyla (1994)
Ground Level	Plastic Scintillator	196	30-2700	$8,7 \times 10^{-2}$	Laurec (1996)
<33 mwe*	Plastic Scintillator at the top	485	50-2700	$6,8 \times 10^{-2}$	Semkov (2002)
Ground Level	NaI Scintillator	125	25-1600	$5,4 \times 10^{-2}$	El-Daoushi (1995)
30 mwe	None	***487***	***30-2700***	***$4,2 \times 10^{-2}$***	MEL Ulab
Ground Level	Plastic Scintillator	125	100-2000	$4,1 \times 10^{-2}$	Miley (1992)
15 mwe	Proportional Counter	170	50-2680	$2,7 \times 10^{-2}$	Heusser (1991)
5 mwe	NaI Scintillator	106	20-4000	$9,4 \times 10^{-3}$	Beda (2000)
500 mwe	None	40	20-2700	$9,4 \times 10^{-3}$	Mouchel (1996)
4400 mwe	None	207	20-2000	$8,2 \times 10^{-3}$	Bourlat (1994)
30 mwe	***Plastic Scintillator 5 faces***	***487***	***30-2700***	***$5,8 \times 10^{-3}$***	MEL Ulab
500 mwe	None	234	40-2700	$2,0 \times 10^{-3}$	Hult (2000)
800 mwe	None	560	100-2200	$9,9 \times 10^{-4}$	Jagam (1988)
3300 mwe	None	411	50-2750	$6,1 \times 10^{-4}$	Neder (2000)
4000 mwe	None	200	100-2000	$1,3 \times 10^{-4}$	Miley (1992)

Anti-cosmic Spectrometers

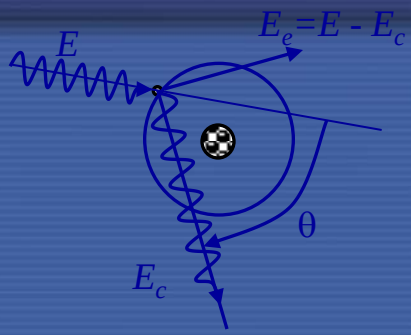
Comparison with other U-Lab



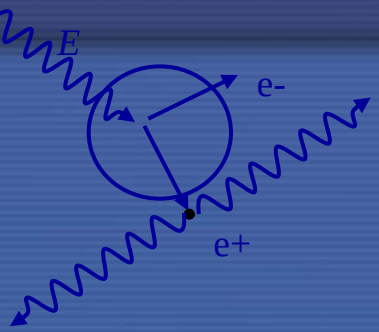
The Anti-Compton Spectrometer



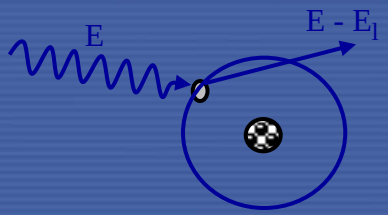
Anti-Compton Spectrometer and Marine Samples



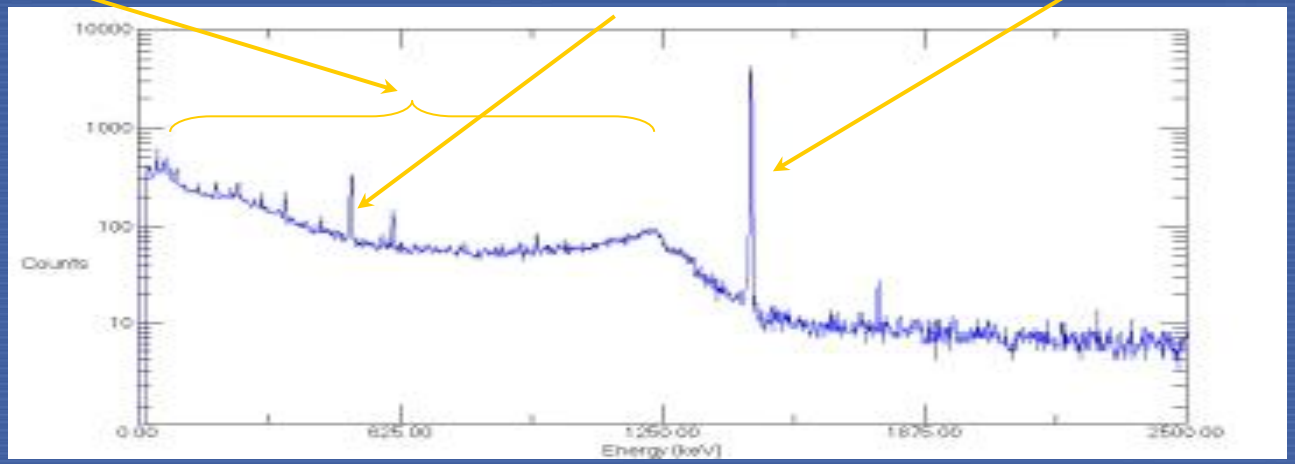
Compton Effect
(continuous distribution)



Pair Production
(512 keV)

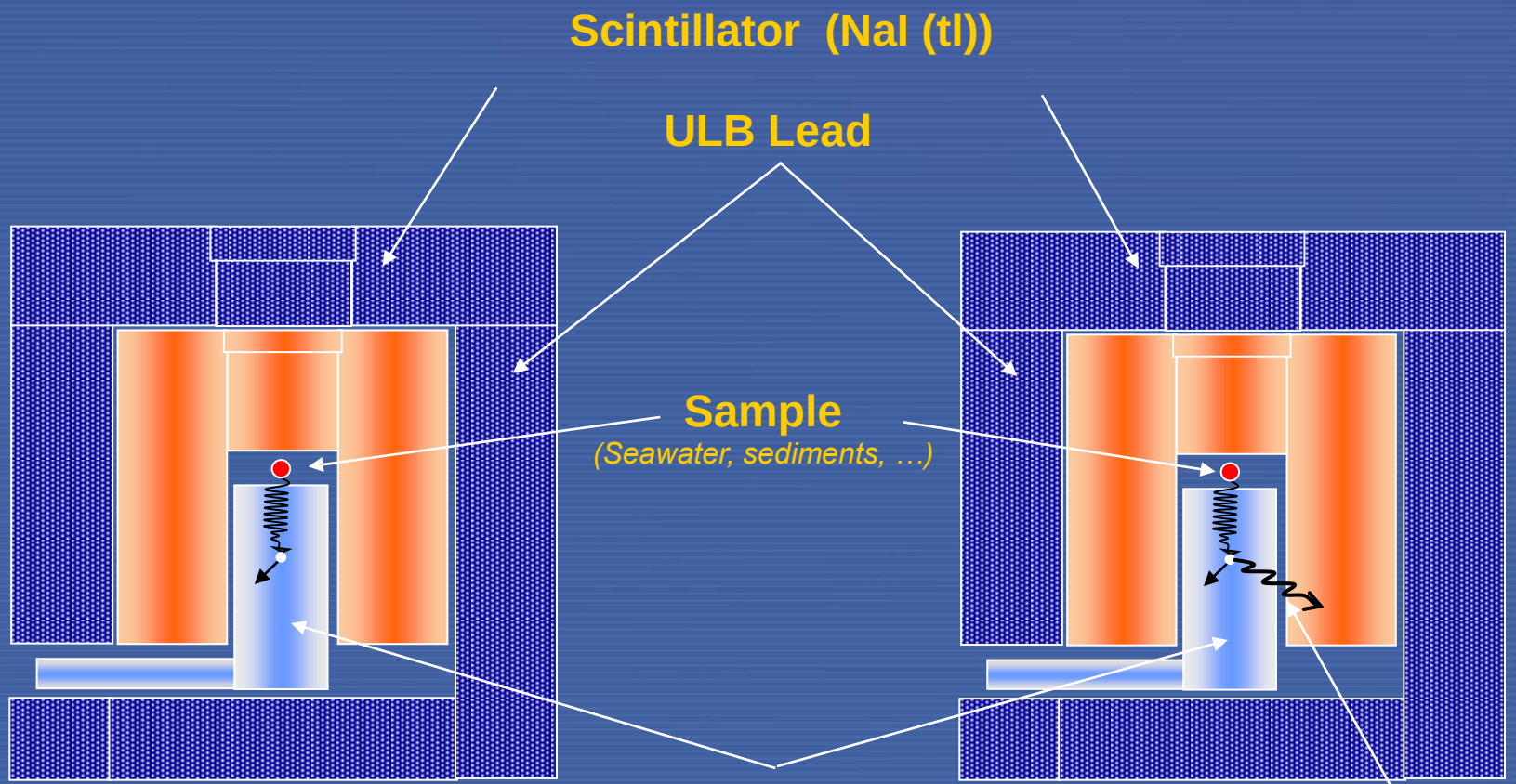


Photoelectric Effect
(Pic ^{40}K (1460 keV))



Marine Salt Gamma Spectrum

The Anti-Compton Spectrometer



YES
(Count accepted)

No
(Compton detected by NaI detector)
Count not accepted,

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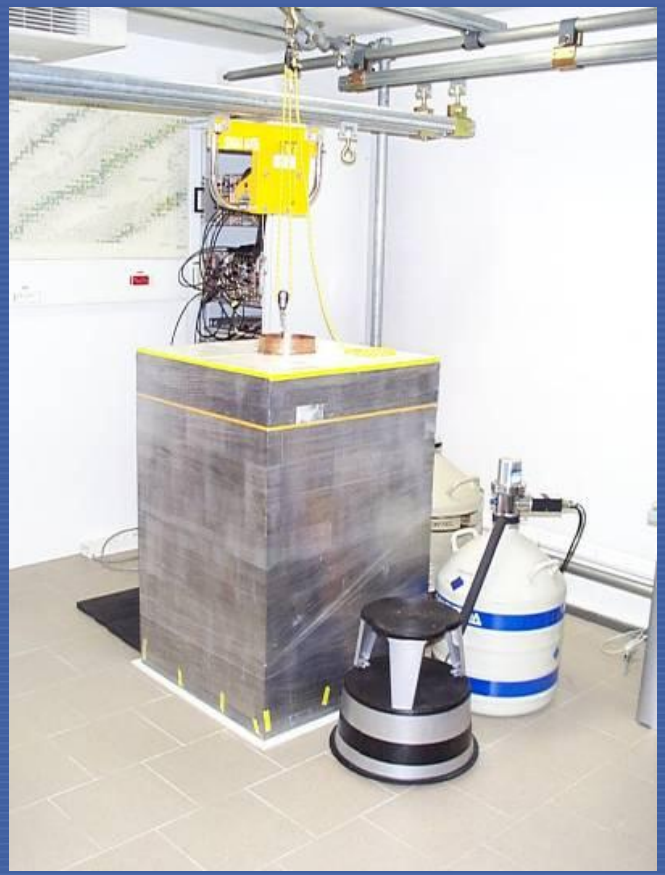
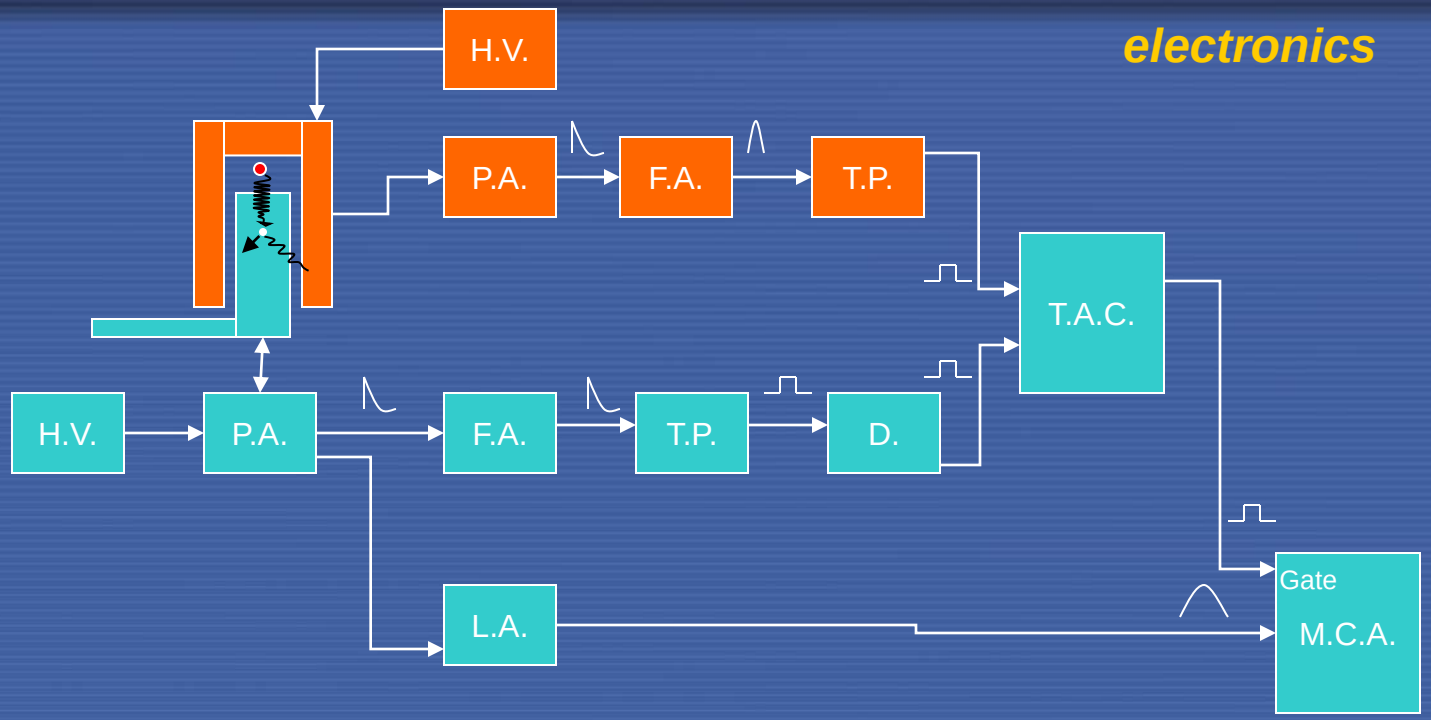
The Anti-Compton Spectrometer

The Anti-Compton Spectrometer



The Anti-Compton Spectrometer



H.T. : High Voltage

P.A. : Preamplifier

T.A.C. : Time Amplitude Converter

A.R. : Fast Amplifier

L.A. : Linear Amplifier

D. : Delay

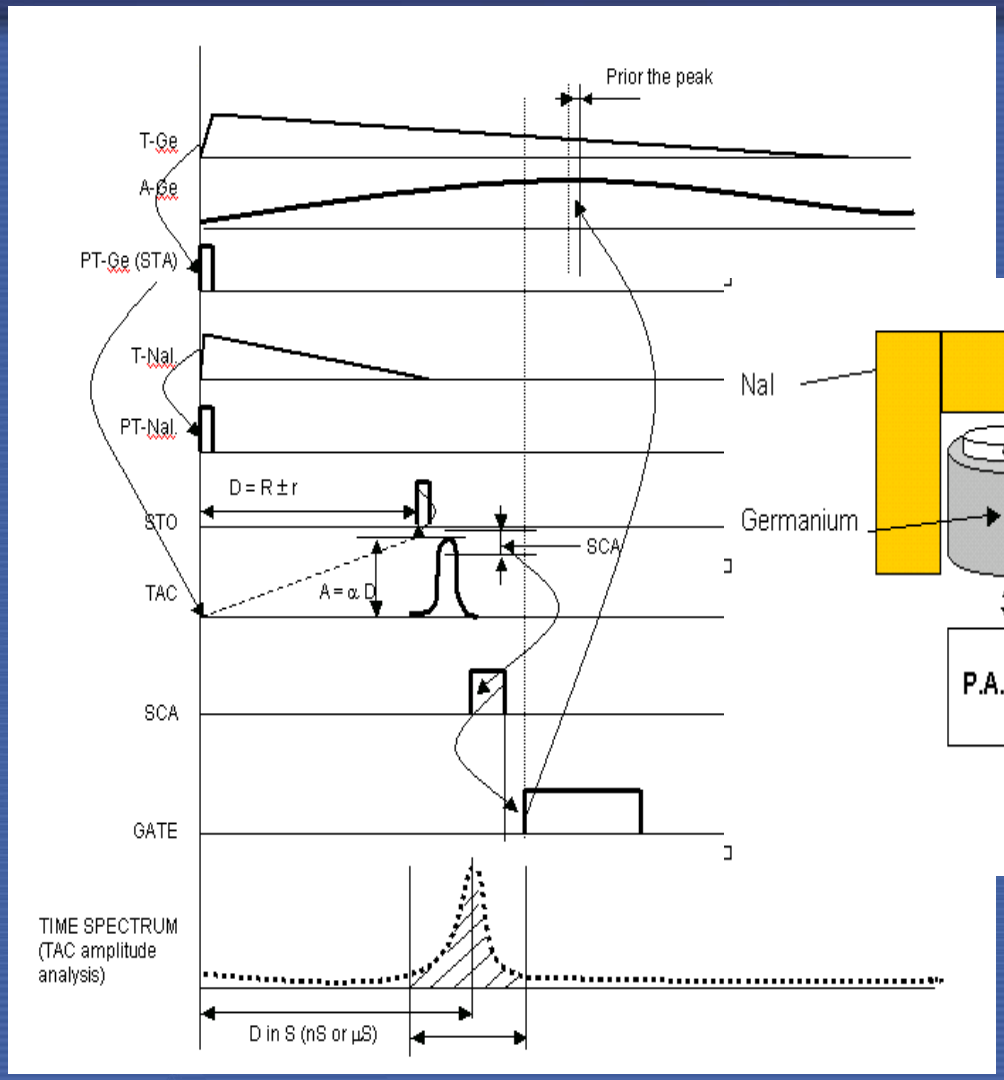
S.C.A. :Single Channel Analyzer

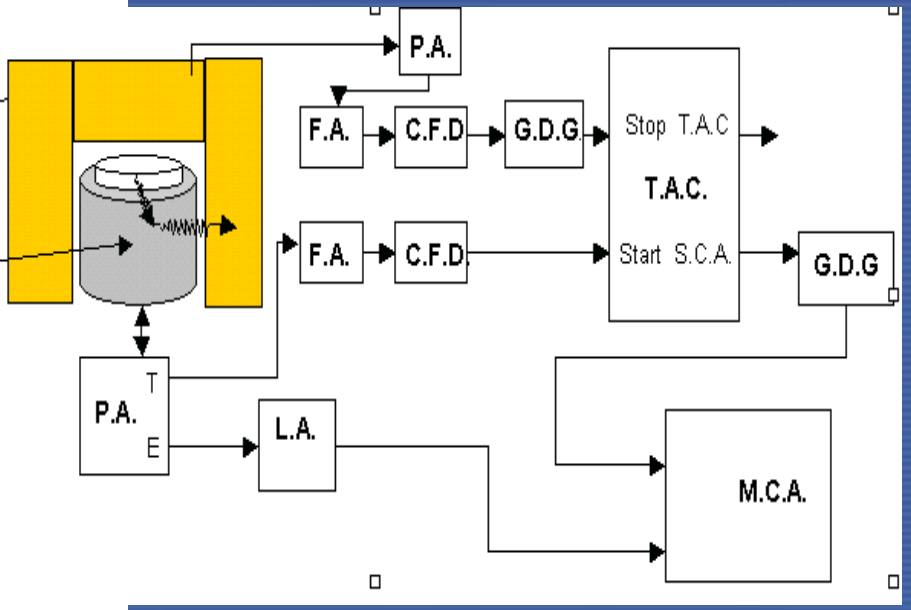
M.C.A. : Multi Channel Analyzer

T.P. : Time Pickoff

The Anti-Compton Spectrometer

chronograms





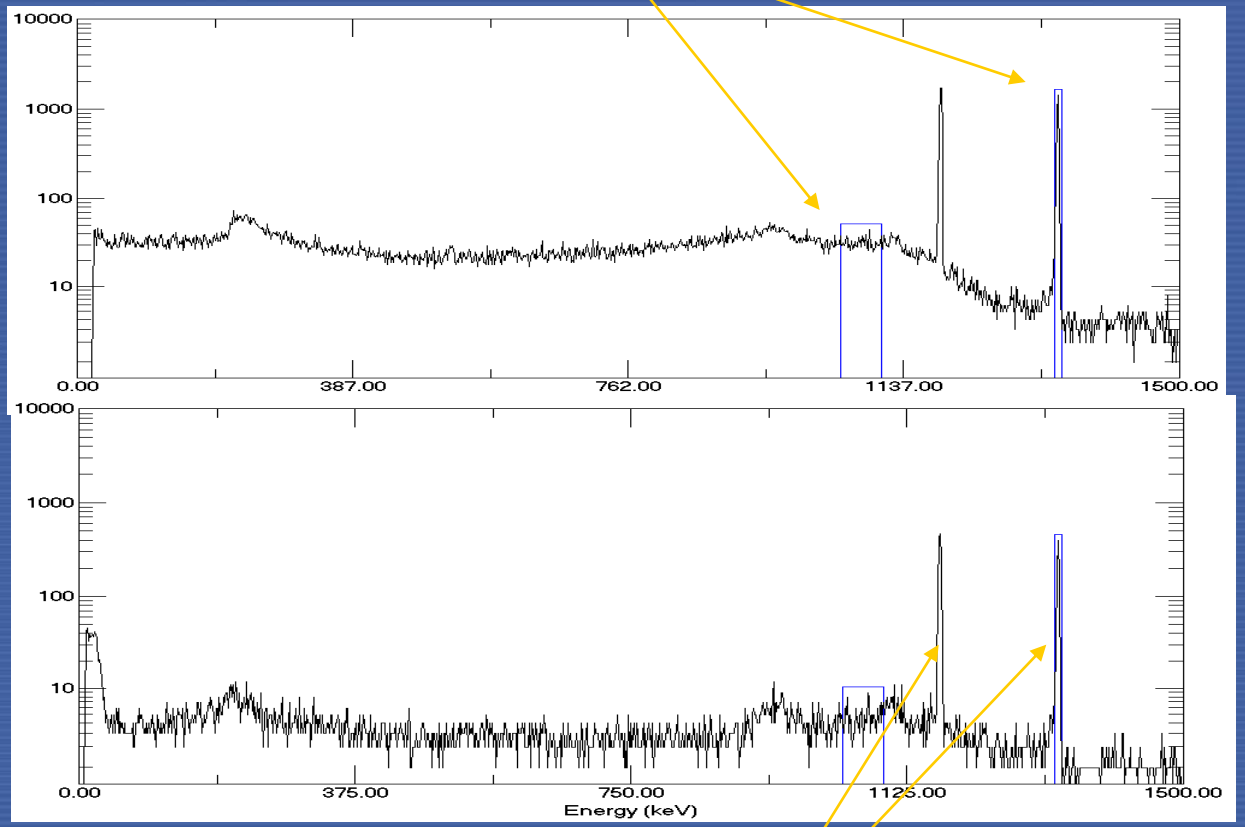
The Anti-Compton Spectrometer Results

^{60} Co: A= 2,8

P/C=57

Direct mode

Anti-Compton mode



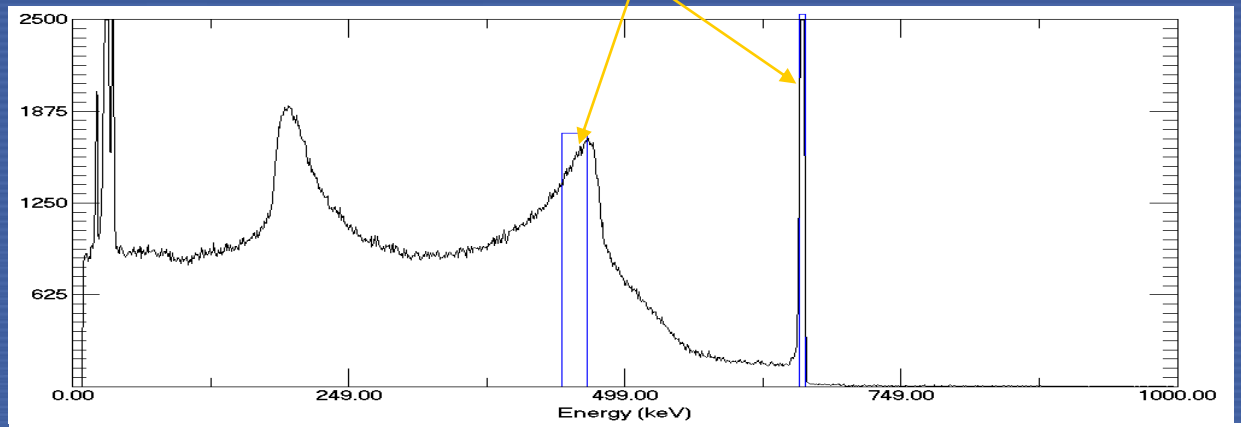
P/C=160

The Anti-Compton Spectrometer Results

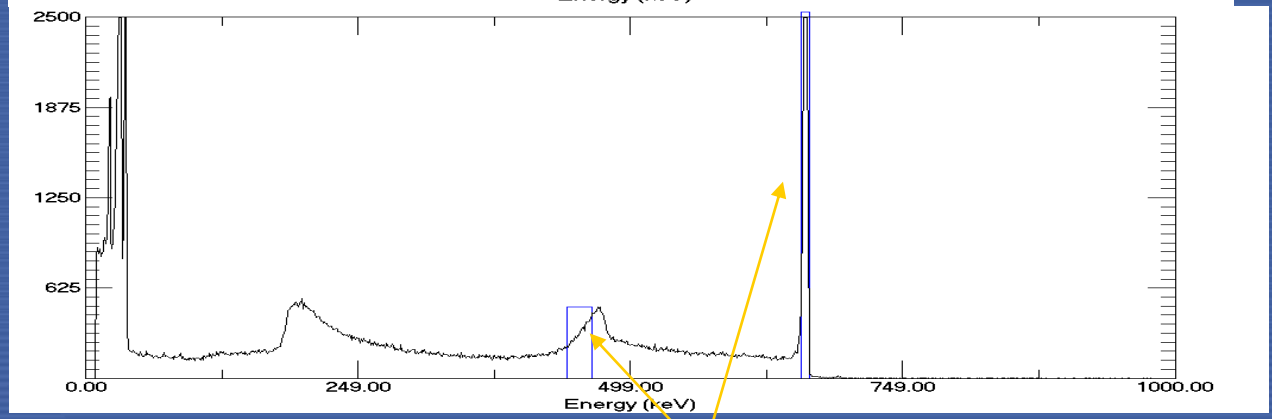
^{137}Cs: A = 4,7

P/C = 91

Direct mode



Anti-Compton mode



P/C= 427

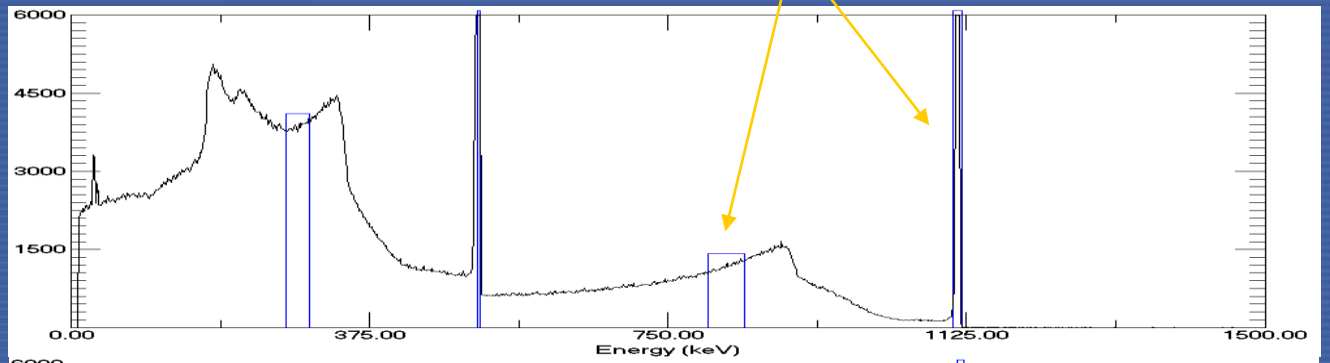
The Anti-Compton Spectrometer Results

^{85} Sr: A= ??

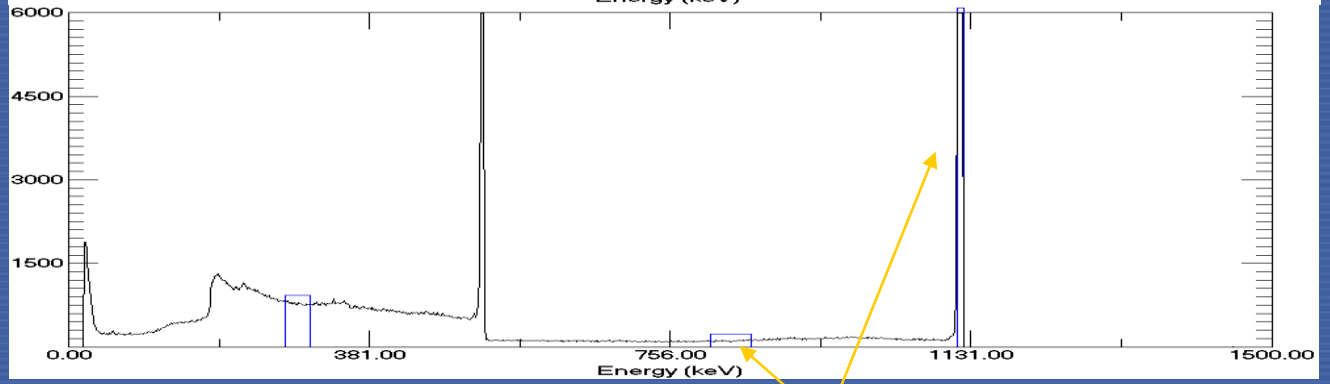
^{65} Zn: A= 11,5

P/C = 86

Direct mode



Anti-Compton mode

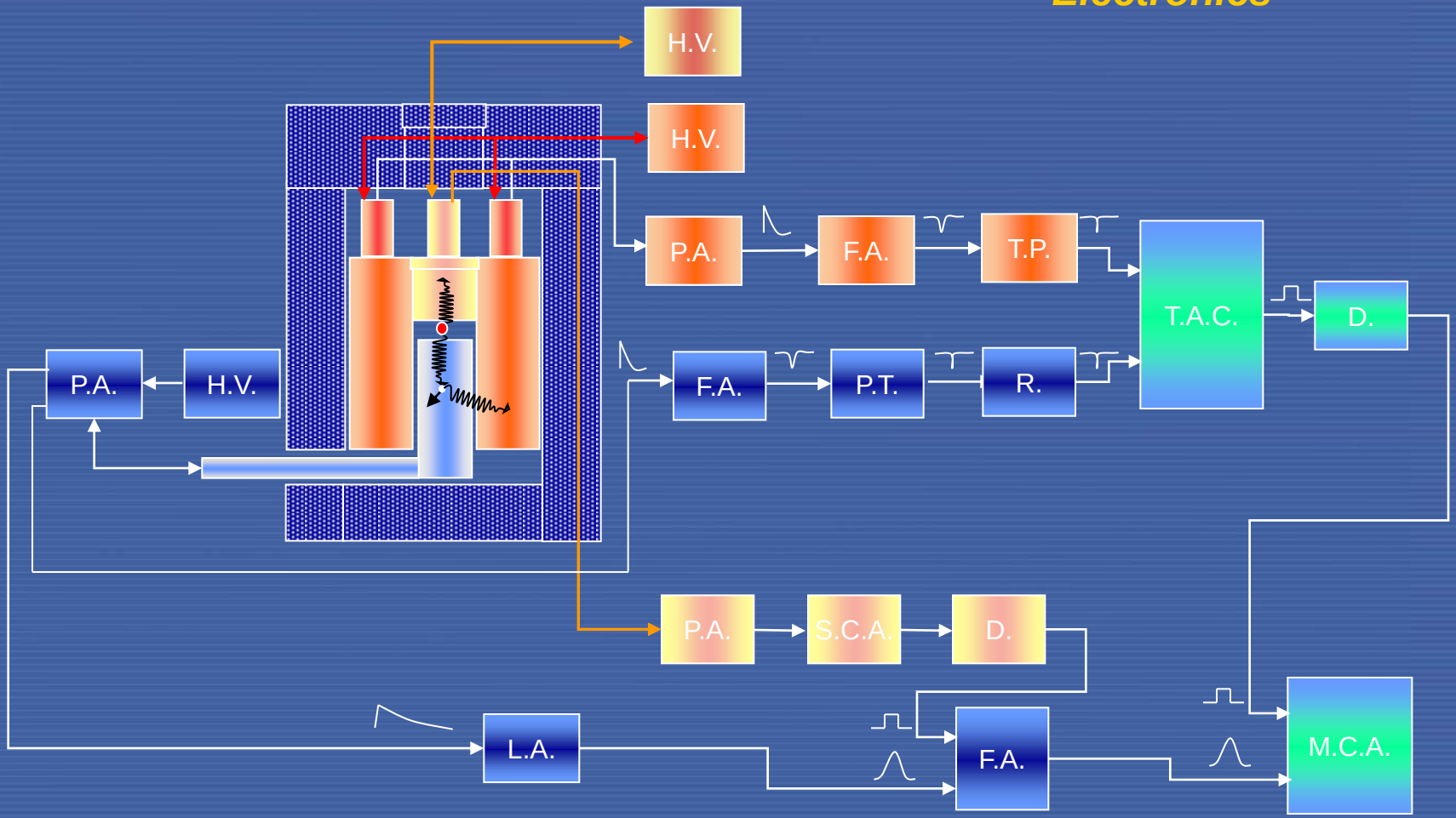


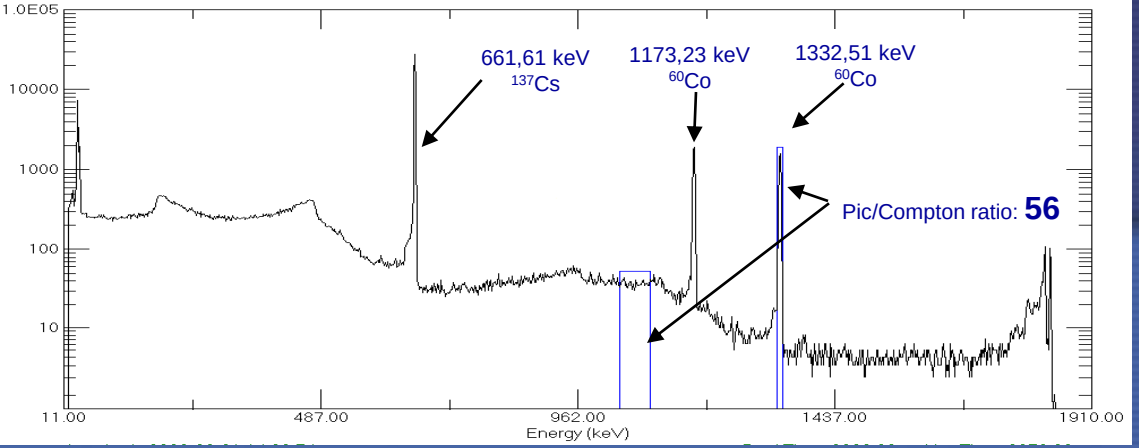
P/C= 960

The Anti-Compton Spectrometer and γ–γ Coincidences

The Anti-Compton Spectrometer and γ–γ Coincidences

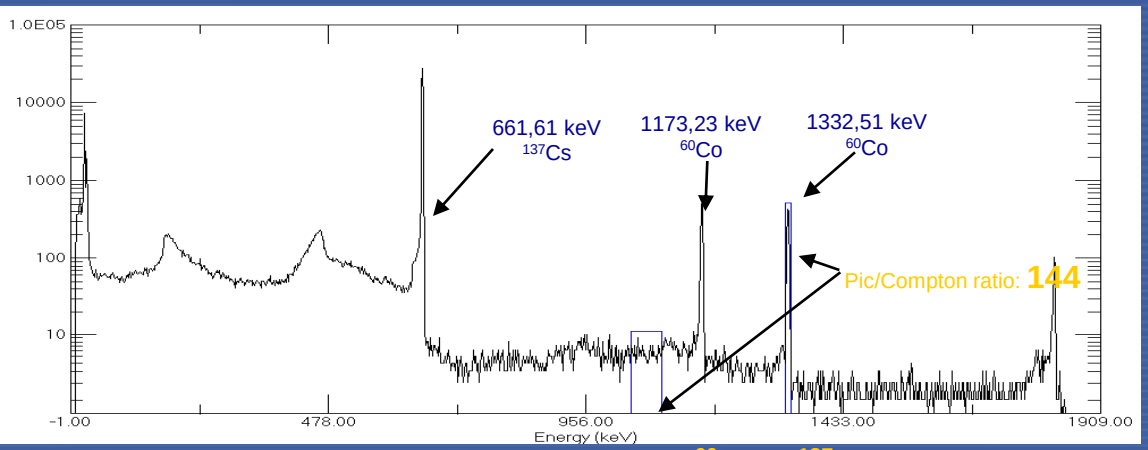
Electronics



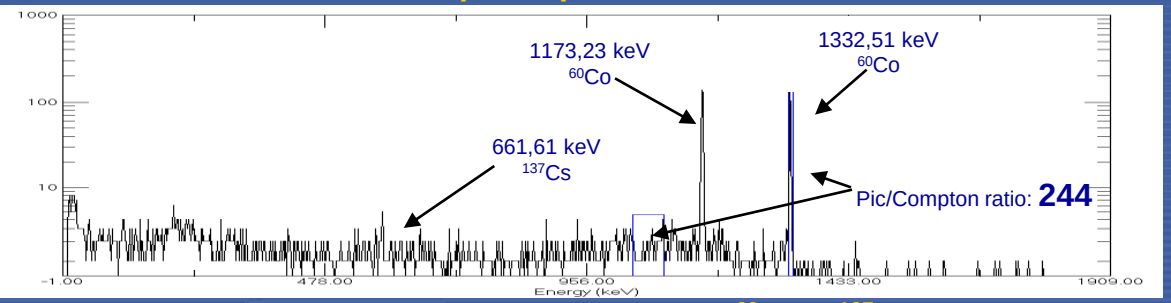


Direct Spectrum ^{60}Co + ^{137}Cs

γ–γ Coïncidence + anti-Compton Spectrometer : Results



anti-Compton Spectrum ^{60}Co + ^{137}Cs



γ–γ coincidence + Anti-Compton ^{60}Co + ^{137}Cs

The new techniques have opened doors for investigations

- which previously required too large samples
- were not possible because of lack of sensitivity
- were not possible because of lack of precision

Conclusion

GOALS : ACHIEVED !

- To decrease the background and to increase the sensitivity of the gamma spectrometers: 0.02 cps between 20 et 2500 keV using 100% to 200% efficiency HPGe detector

- To decrease the size of the Marine Samples: factor of 10

- To decrease the measurement duration: factor of 5

More than 2000 samples has been measured since 2003


THANK YOU